UNIVERSIDAD DE TALCA

KIPUS – Retrofitting Optimization Tools

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What is Kipus?

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kipus

E³

ENERGY INVESTMENT OPTIMIZATION

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Research context

- Energymon: Development of wireless sensor network based Decision Support System to monitor building energy performance. IEEE, 2011, P. Szems et al. (MFKK Inv. and Research Centre Hungary).
- A multi-objective approach for optimal prioritization of energy efficiency measures in buildings: Model, software and case studies. M. Karmellos et al. 2015. Edinburgh, Athens
- Energy Audit Tool Overview , CBEI, 2013, R. Leicht, et al. Inverse modeling using previous data, estimates building parameters.
- Hybrid approach to energy modeling. LBNL, DOE, 2014-2016. Hong, T. It combines physics & measured data. New feature for EnergyPlus V8.6

Market context

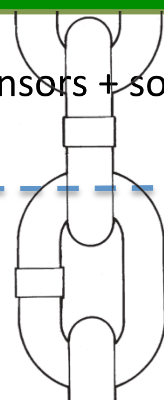
a)

Sensors & HVAC Suppliers

- Traditional
- New players

BEMS

- Sensors + software



Controlling
Re-commissioning
Operational measures

BUILDINGS OWNERS

b)

Software tools

- Data aquisition
- Energy modelling

Energy Auditors

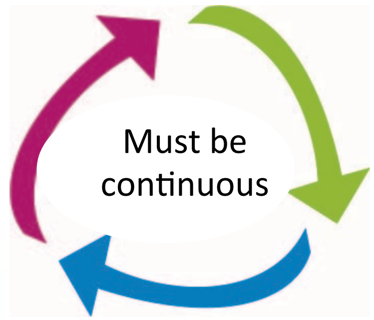
- Pen & Paper audit
- Supported by software
- Virtual assessment

Retrofitting
Re-commissioning
Operational measures

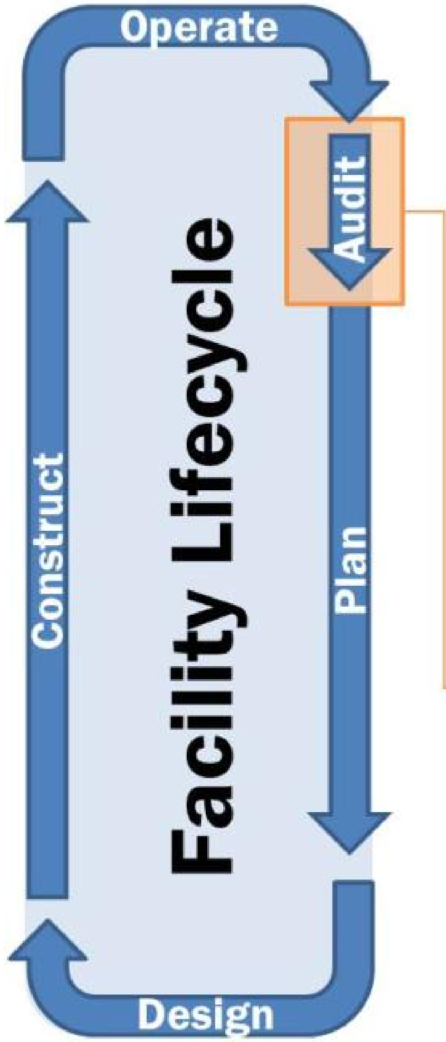
ESCOs

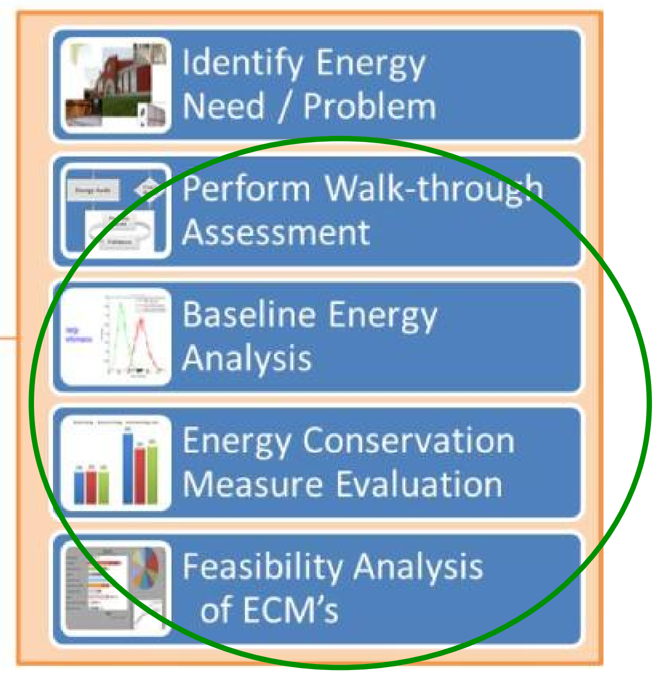
CONTRACTORS

Problem statement



Investment vary
Operation vary
New tecnologies…





Time-consuming
Missing data
Accuracy
Divergent ECMs

CBEI, 2013

Figure 4: Alignment of Energy Auditing in the Facility Lifecycle

Problem statement

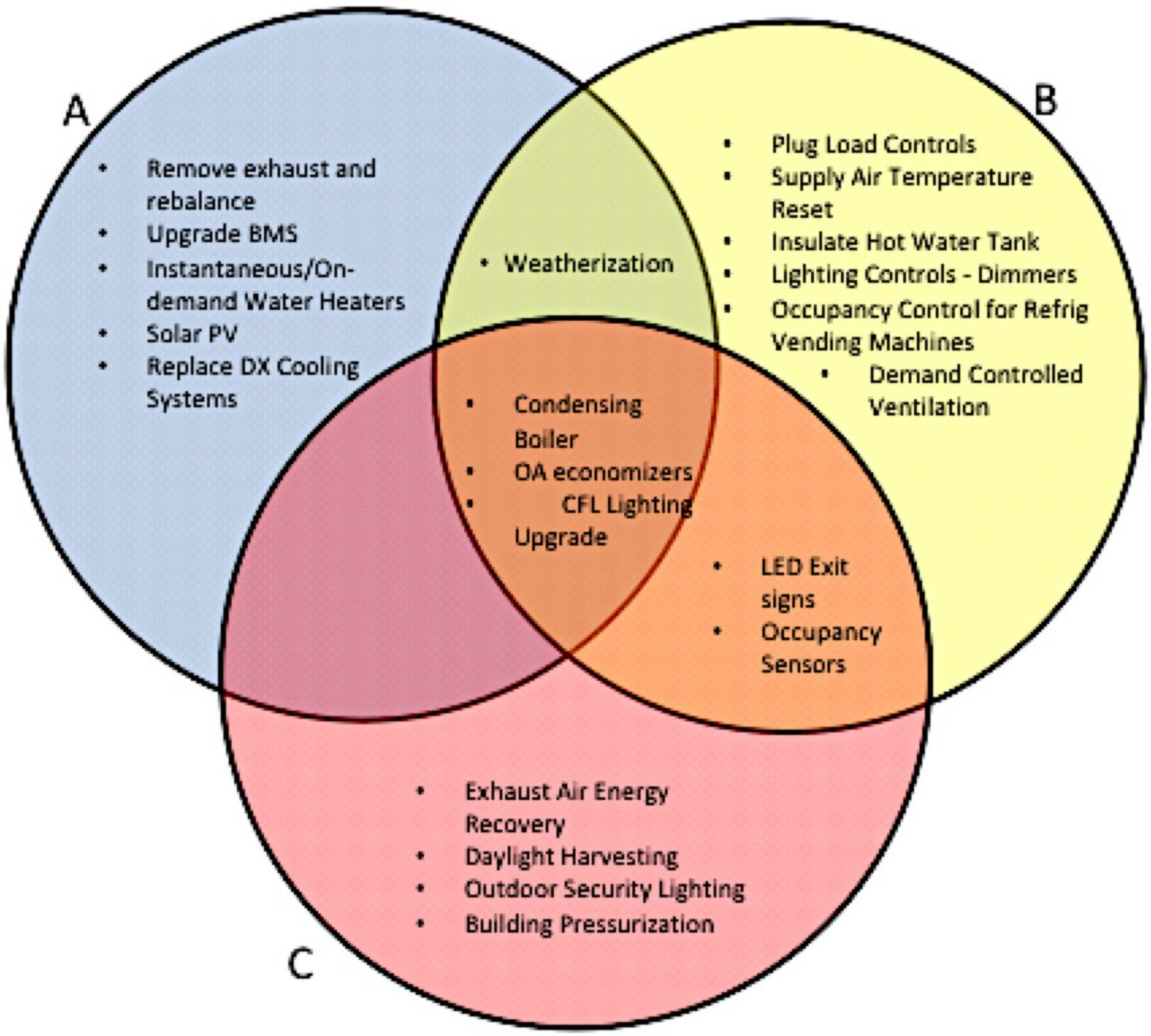


Figure 1: Venn diagram of recommended ECMs from three separate analyses by Companies A, B, and C.

CBEI, 2013

Problem statement

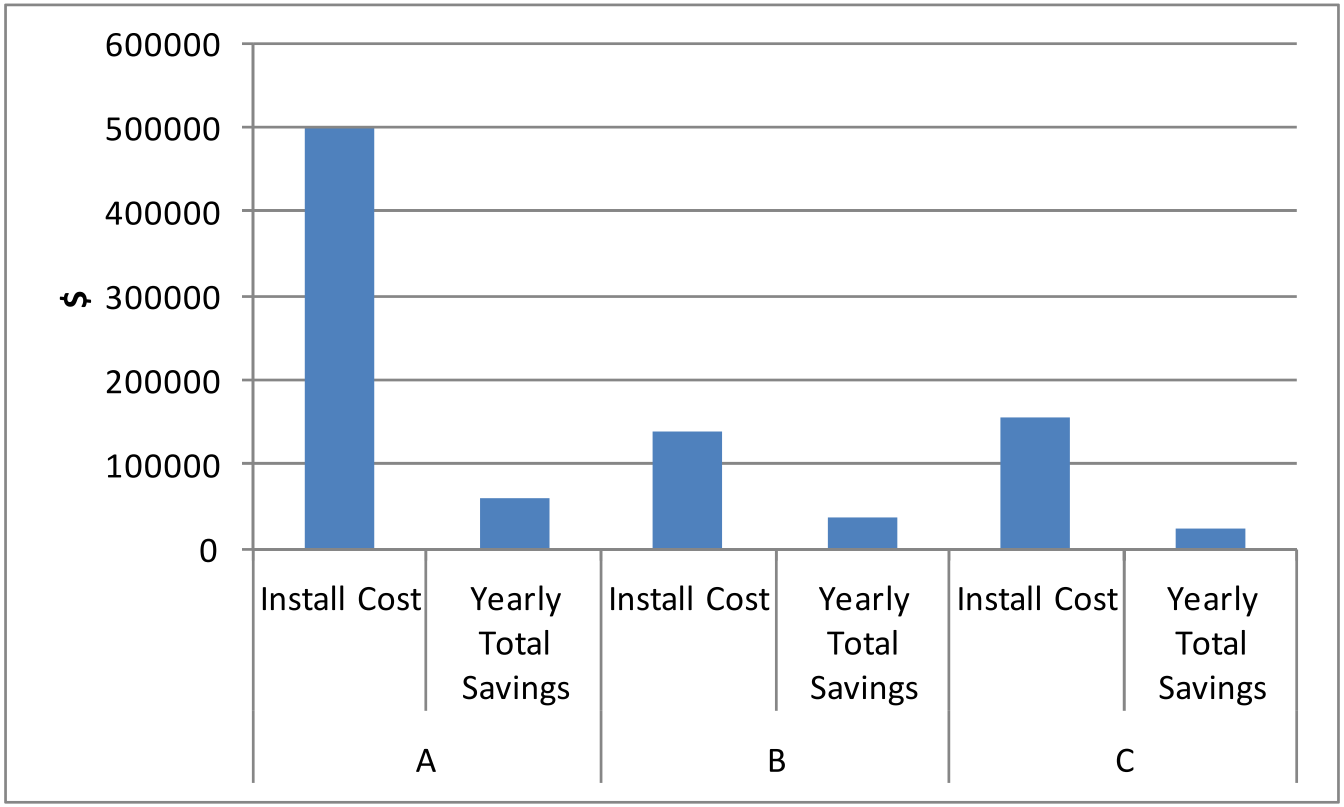
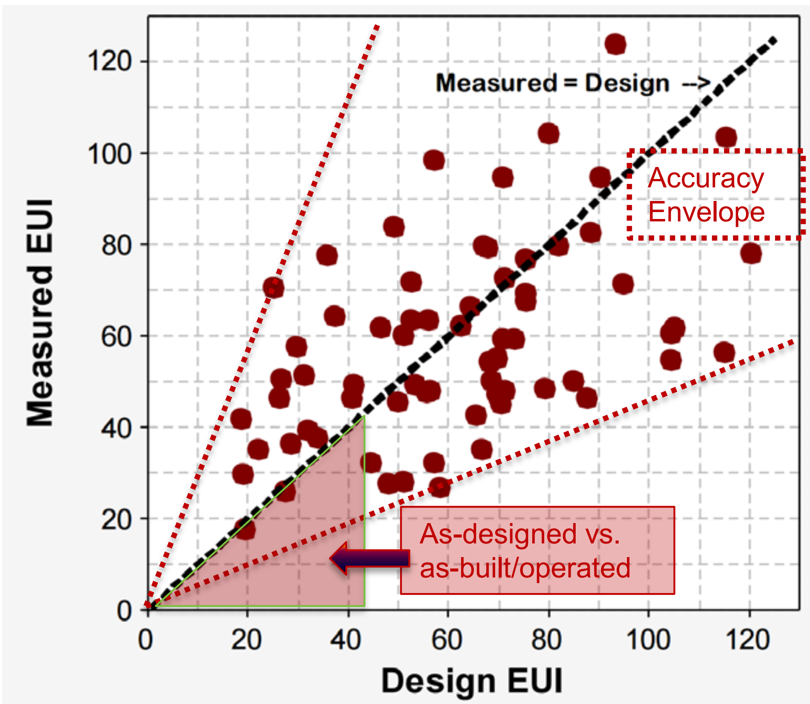


Figure 2: Installation costs and yearly savings for ECM packages proposed by Companies A, B, and C.

Problem statement

Building energy modelling:

- "A ±30% proposition at best…
- …Not accurate enough to support investment…
- …Can't predict energy use…"



Source: U.S. DOE

Our approach

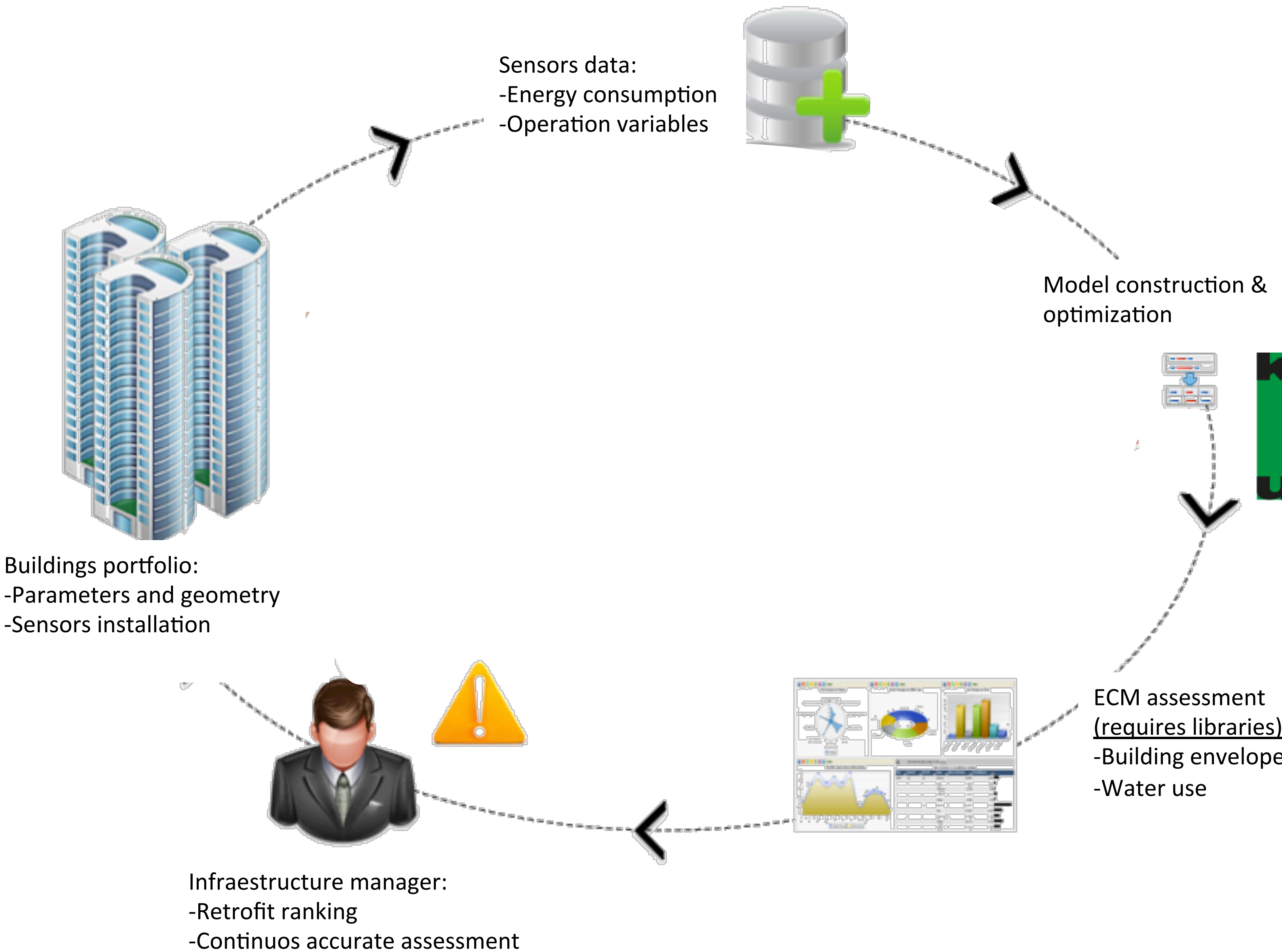
A tool that:

- serves for a cost-effective retrofitting assessment and supports continuous investment decision-making.
- uses data from sensors to sink audit costs and to improve the accuracy of building energy assessment.
- allows continuous modeling for continuous improvement

The tool uses an inverse optimization algorithm that:

- approximates the thermodynamical behavior by means of a linear function (linear factors)
- uses parameters and geometry obtained onsite or from drawings
- determines the best factors for building modeling
- uses proxy variables (CO_2, person counter, humidity, etc.) for estimating hard to read variables e.g. ventilation and infiltration.

Our approach



The algorithm

Heating and cooling energy depends on:

- *building parameters B (input)*
- *weather W (measured)*
- *user behavior U (measured)*

$$I = B \cup W \cup U.$$

$$Q_{z,t} = Q_{z,t}^{\mathrm{Trans}} + Q_{z,t}^{\mathrm{Vent}} + Q_{z,t}^{\mathrm{Rad}} - Q_{z,t}^{\mathrm{Sol}} - Q_{z,t}^{\mathrm{Int}} + Q_{z,t}^{\mathrm{Losses}} \qquad [W\|t\|],$$

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The algorithm

$$Q^{\mathrm{Trans}}_{z,t} = \beta^1_z \times \sum_{i \in B_z} A_i \times U_i \times Fx_i \times \Delta T_i \times \|t\|,$$

$$Q^{\mathrm{Vent}}_{z,t} = \beta^2_z \times \frac{1}{\mathrm{CO}_{2_z}} \times \frac{1}{p^{\mathrm{int}}_z} \times n^{\mathrm{pers}}_{z,t} \times V_z \times 0.34 \times \Delta T^{\mathrm{vent}}_z \times \|t\|,$$

$$Q^{\mathrm{Rad}}_{z,t} = \sum_{j \in J} R^{se}_{j,z} \times A''_{j_z} \times U_{j_z} \times \left(\beta^7_{j_z} \times \Delta T^{\mathrm{rad}}_z - \beta^8_{j_z} \times I^h\right) \times \|t\|.$$

$$Q^{\mathrm{Sol}}_{z,t} = \sum_{j \in J} \beta^6_{j_z} \times A'_{j_z} \times I^h \times \|t\|.$$

$$Q^{\mathrm{Int}}_{z,t} = \left(\beta^3_z \times n^{\mathrm{pers}}_{z,t} + \beta^4_z \times Q^{\mathrm{il}}_z + \beta^5_z \times Q^{\mathrm{eq}}_z\right) \times \|t\|.$$

$$Q^{\mathrm{Losses}}_{z,t} = \beta^9_z \times \|t\|.$$

The algorithm

The accuracy of a given configuration of such factors is assessed:

$$\epsilon_1(\boldsymbol{\beta}') = \frac{\left|\sum_{t=1}^{M}\sum_{z=1}^{Z} Q'_{z,t} - \sum_{t=1}^{M}\sum_{z=1}^{Z} Q_{z,t}\right|}{\sum_{t=1}^{M}\sum_{z=1}^{Z} Q_{z,t}},$$

Relative error: energy consumption forecast using a particular factor setting β' and measured energy cosumption

$$\epsilon_2(\boldsymbol{\beta}') = \sum_{z=1}^{Z}\frac{Q_z}{Q}\sum_{t=1}^{M}\left(\frac{\left|Q'_{z,t} - Q_{z,t}\right|}{Q_{z,t}}\right)$$

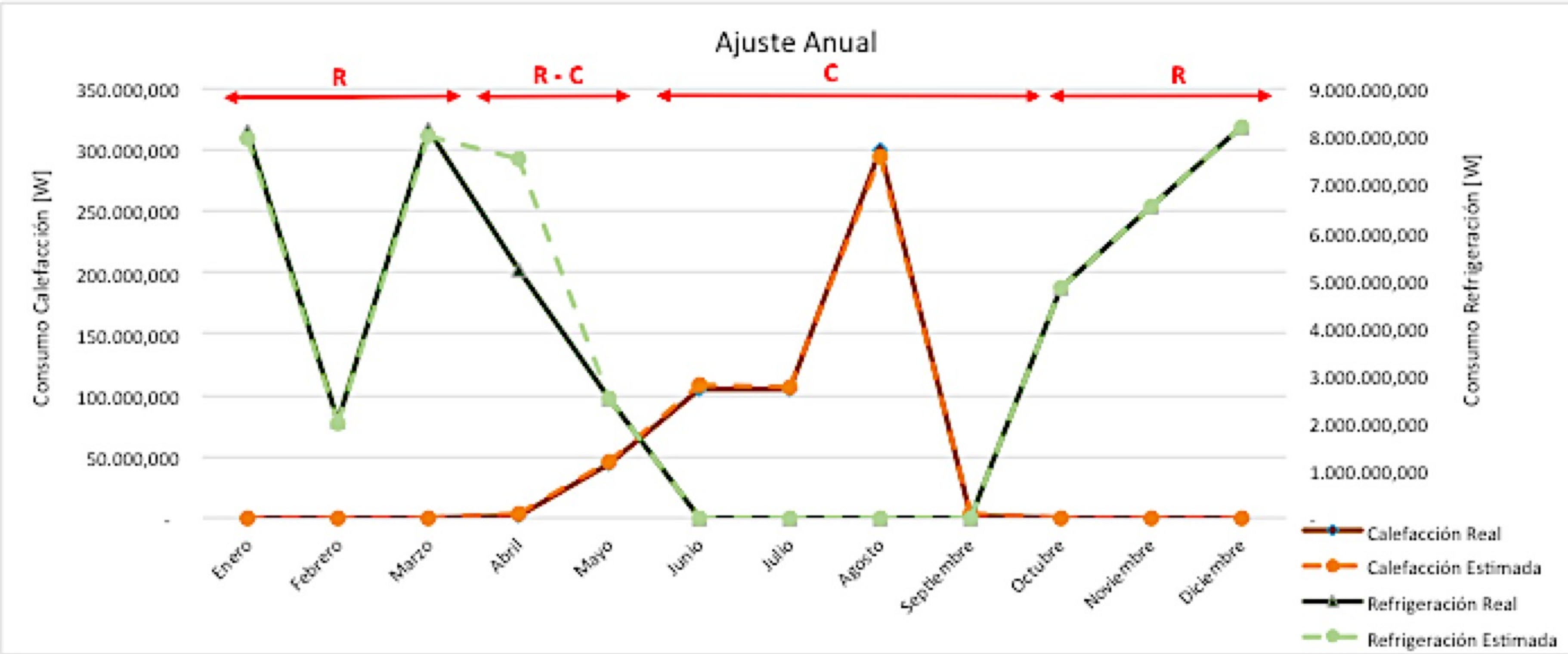
Relative error per zone

A particular vector β' might induce a very small error ε1(β') but a high error ε2(β'), or vice-versa. The goal of the algorithm is to find a vector β∗ that provides a good balance between ε1(β∗) and ε2(β∗).

Preliminary results

- 10^6 multipliers combinations
- 10^5 multipliers combinations for each zone
- Less than two hours computation
- Algorithm tested first using building modeling software TAS, less than 1% deviation
- Algorithm being tested in a building

Preliminary results (comparison with TAS)



Case Study

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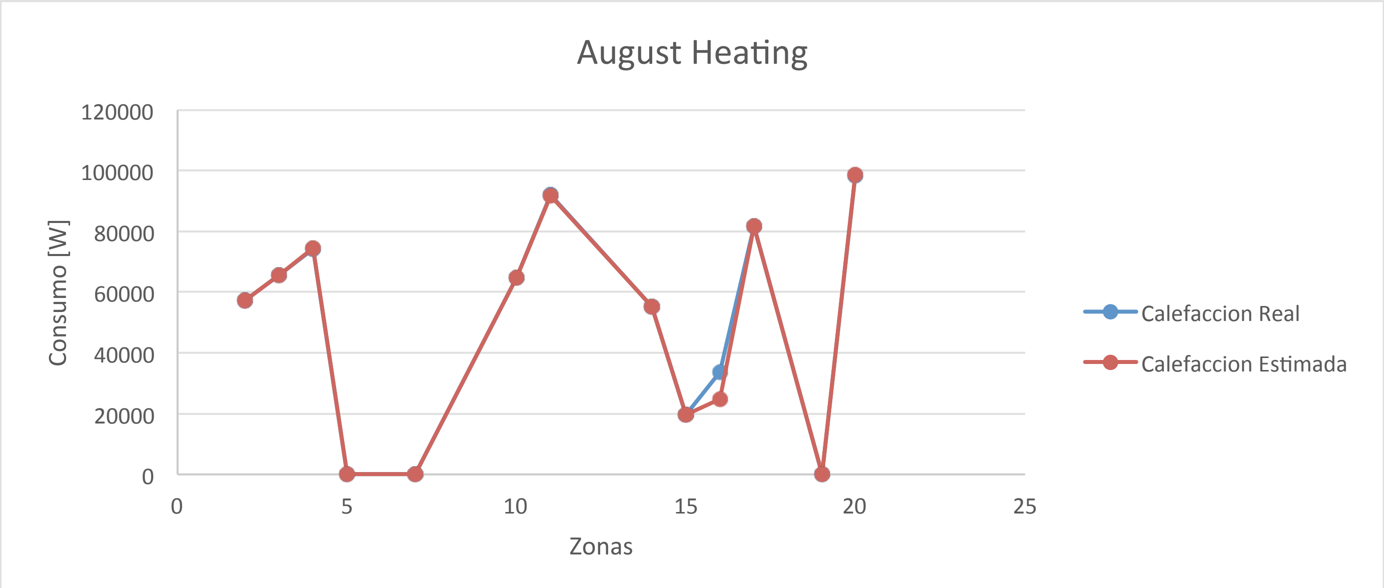
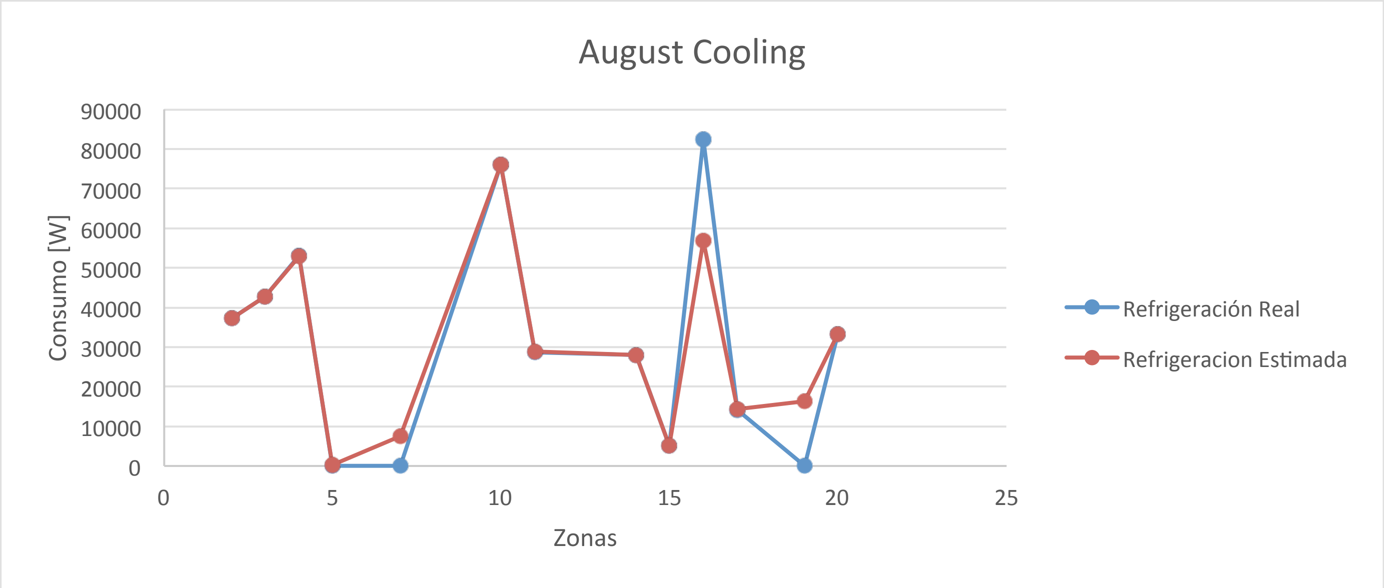
Preliminary results (Real)

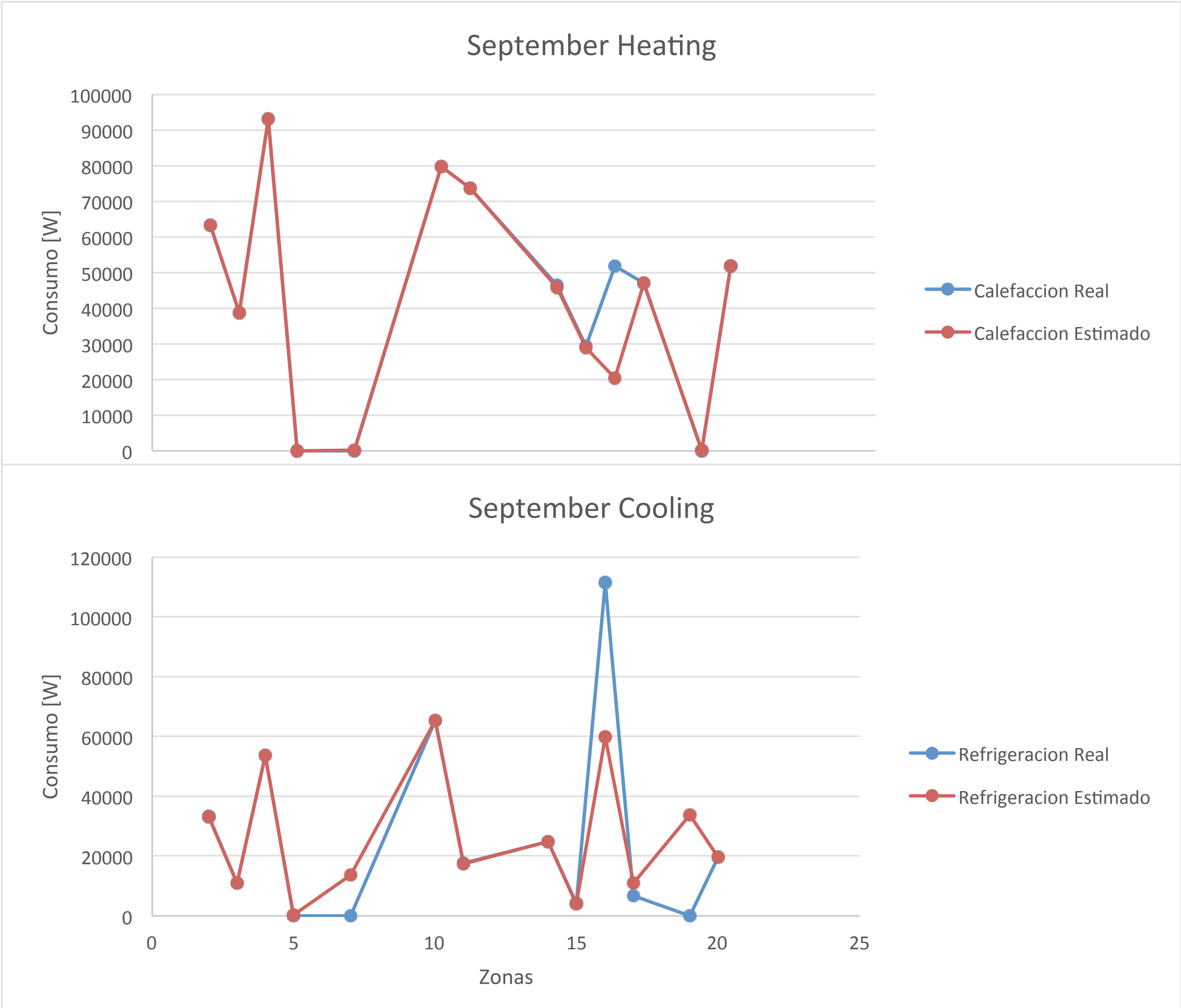


-1,43%



-0,37%

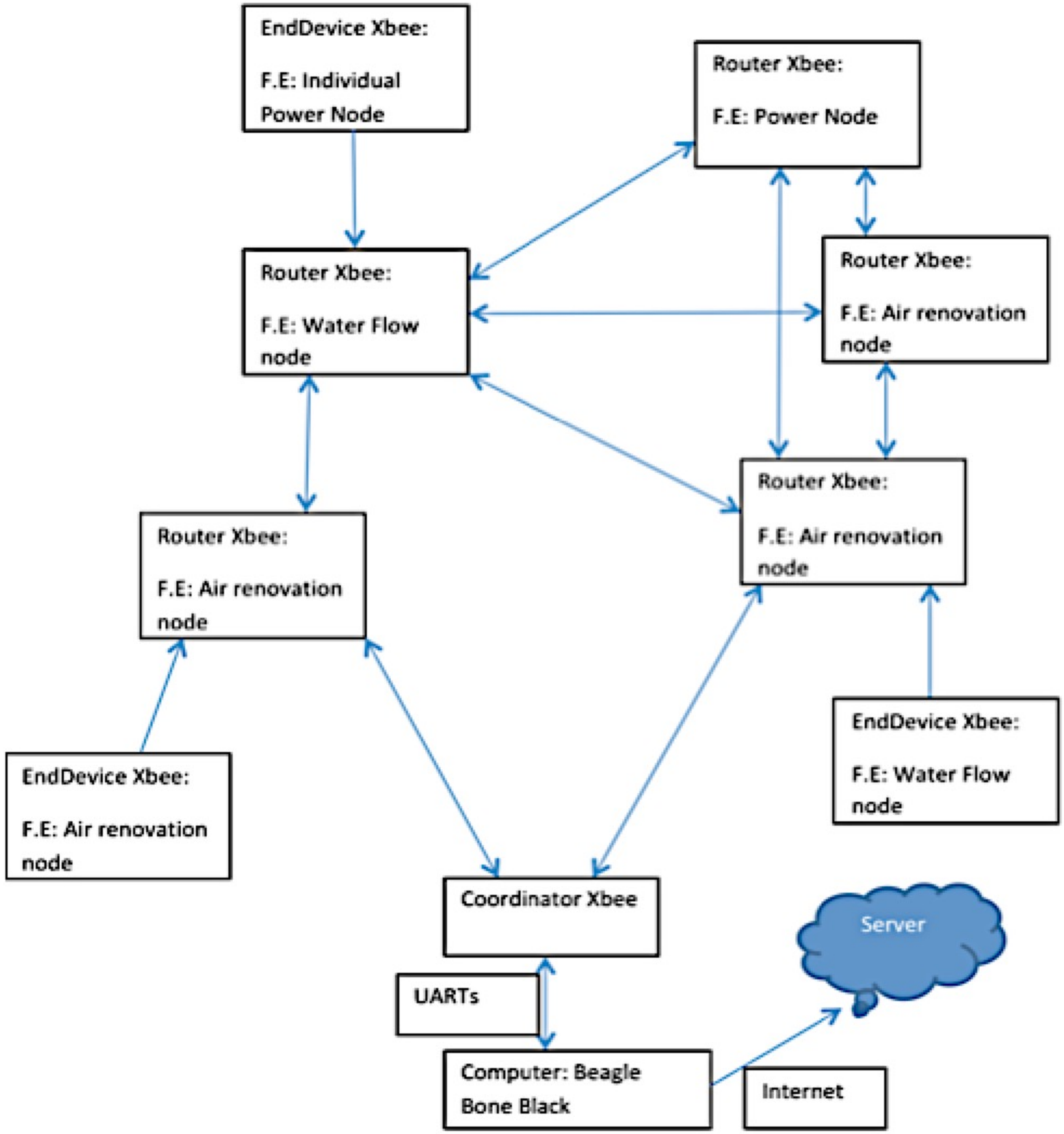
Preliminary results (Real)



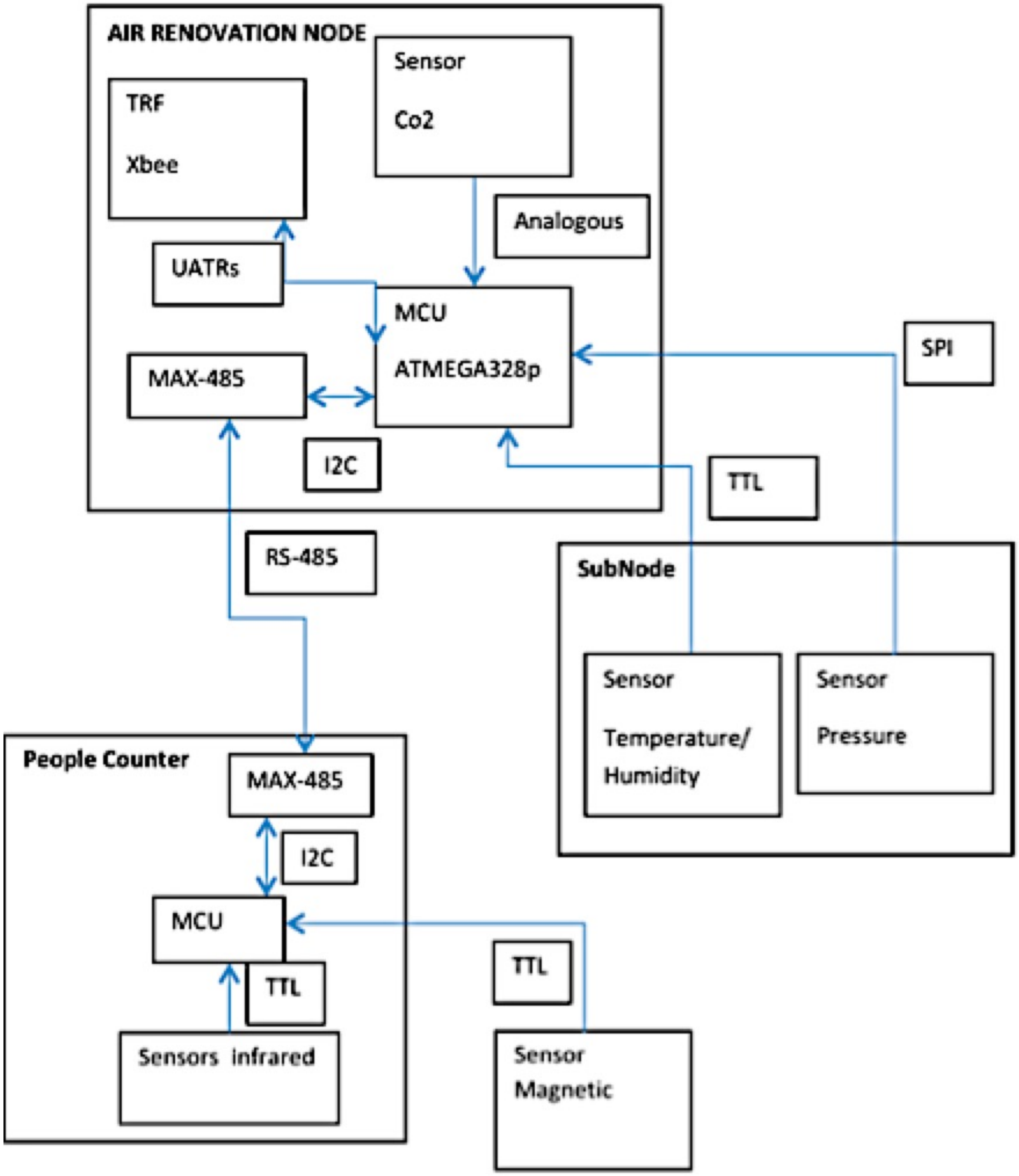
-5,88%

-0,08%

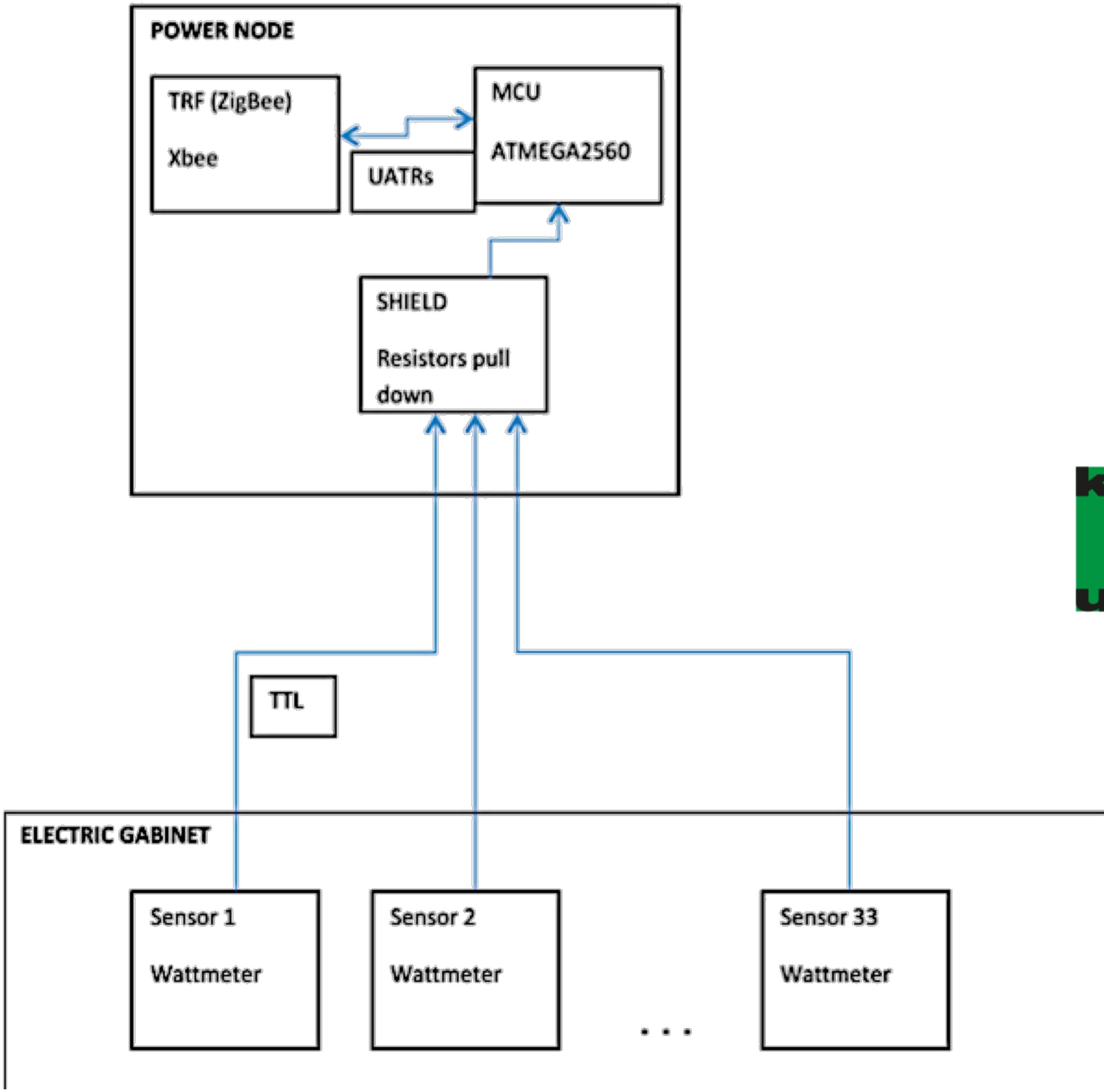
Zigbee mesh overview



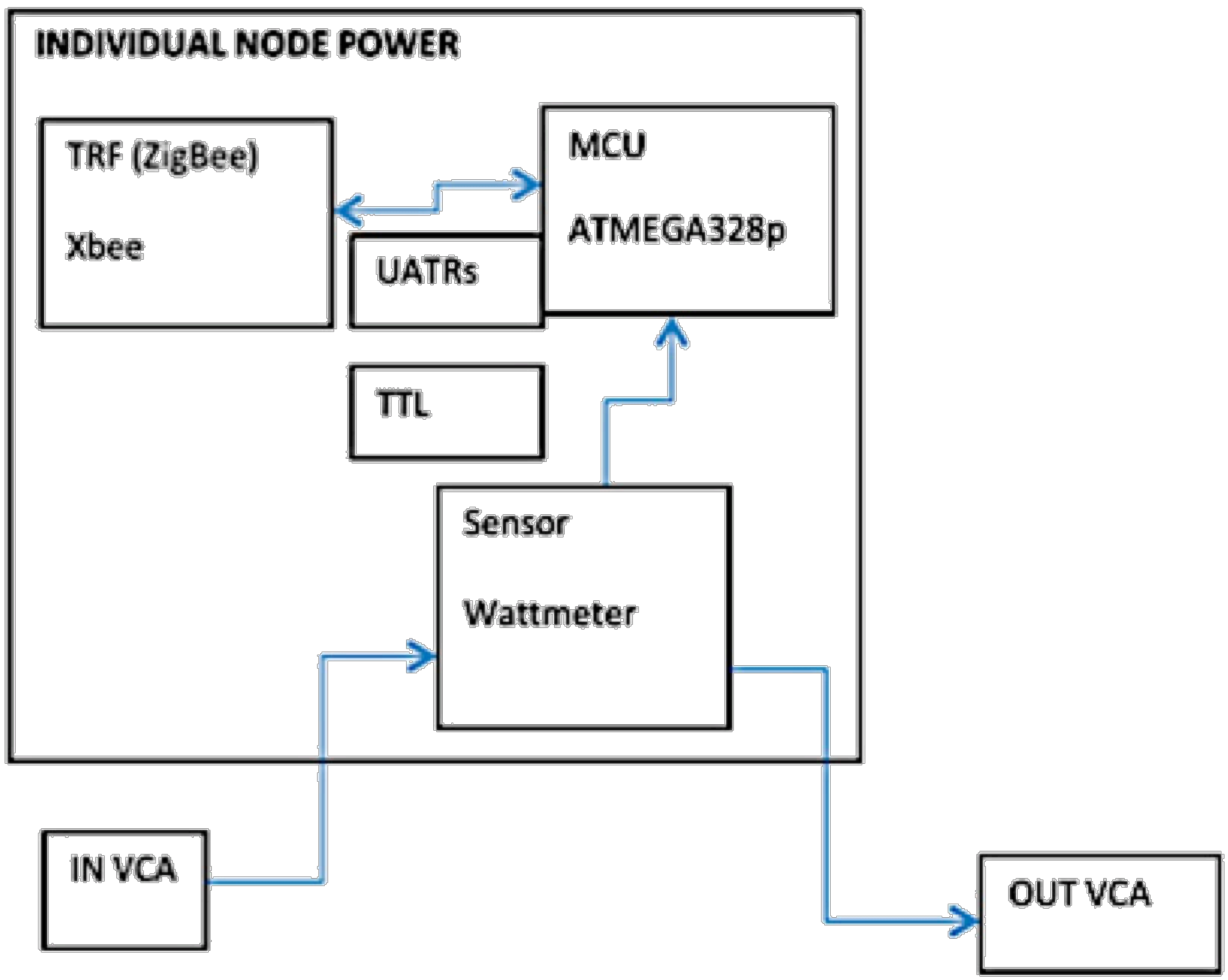
Communication protocols



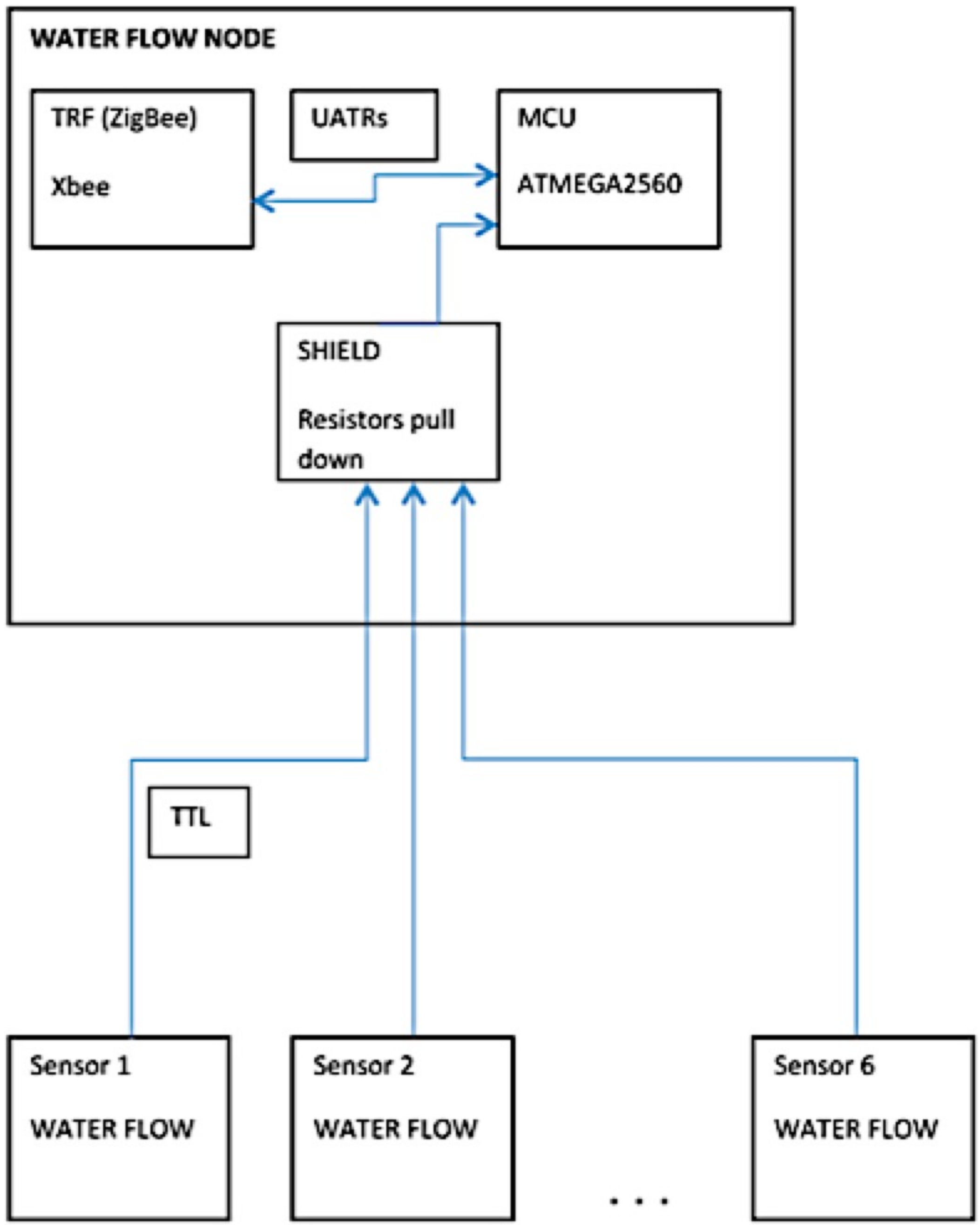
Communication protocols



Communication protocols



Communication protocols



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